

WHAT IS CLAIMED IS:

1. An evaluation method of a semiconductor device comprising:
  - measuring a drain current characteristics of a gate voltage of the semiconductor device;
  - obtaining a threshold voltage and a flat band voltage from a drain current characteristics of a gate voltage of the semiconductor device;
  - obtaining an activated dopant density from the threshold voltage and the flat band voltage; and
- 10 obtaining an added dopant density in the semiconductor device.
2. The evaluation method of the semiconductor device according to claim 1, wherein the added dopant density in the semiconductor device is obtained by secondary ion mass spectrometry analysis.
- 15 3. The evaluation method of the semiconductor device according to claim 1, wherein the activated dopant density and the added dopant density in a channel region of the semiconductor device are obtained.
- 20 4. The evaluation method of the semiconductor device according to claim 1, wherein the activated dopant density and the added dopant density in an impurity region of the semiconductor device are obtained.
- 25

5. The evaluation method of the semiconductor device according to claim 1, further comprising obtaining a dopant activation rate from the activated dopant density and the added dopant density.

5

6. A device design management system comprising:  
a means for measuring drain current characteristics of a gate voltage of a semiconductor device constructing a device;  
a computer having a means for computing an activated dopant density from the drain current characteristics of the gate voltage; and  
a means for measuring an added dopant density in the semiconductor device,

wherein the computer has a function which computes a dopant activation rate from the activated dopant density and the added dopant density, and determines a dose amount from the dopant activation rate.

7. A device design management system comprising:  
a means for measuring drain current characteristics of a gate voltage of a semiconductor device constructing a device, and obtaining a threshold voltage and a flat band voltage; and  
a computer having a means for computing an activated dopant density from the threshold voltage and the flat band voltage, and a dopant activation rate,

wherein the computer has a function to determine a dose amount from the dopant activation rate and the activated dopant density.

8. A device design management system comprising:  
a means for measuring an added dopant density in a semiconductor  
device constructing a device; and

5 a computer having a means for computing a threshold voltage and a  
flat band voltage from the dopant density and a dopant activation rate,  
wherein the computer has a function to determine a dose amount  
from the dopant activation rate, and the threshold voltage and the flat  
band voltage.

10

9. A production method of a semiconductor device comprising:

forming a semiconductor film on an insulating surface;

crystallizing the semiconductor film;

adding dopant to the crystallized semiconductor film at a dose

15 amount, wherein the dose amount of the dopant is determined in  
accordance with a dopant activation rate of the dopant in a channel region  
of the semiconductor film; and

activating the added dopant in the semiconductor film.

20

10. A production method of a semiconductor device comprising:

forming a semiconductor film on an insulating surface;

crystallizing the semiconductor film;

adding dopant to the crystallized semiconductor film at a dose  
amount to form a source region and a drain region, wherein the dose  
25 amount of the dopant is determined in accordance with a dopant activation

rate of the dopant; and

activating the added dopant in semiconductor film.

11. A dose amount control program for a computer that controls

5 a dose amount in a semiconductor device, said computer comprising:

a computing means for computing a dopant activation rate from a threshold voltage and a flat band voltage of the semiconductor device; and

a setting means for setting a predetermined dose amount according to the dopant activation rate obtained from the computing means.

10

12. The dose amount control program according to claim 11,

wherein the computing means obtains an activated dopant density by a formula

$$V_{th} - V_{fb} = (e \cdot n_i / C_{ox}) (N_d / n_i) \cdot [(4\epsilon_0 \cdot \epsilon_{Si} \cdot kT) / (e^2 \cdot (N_d / n_i) \cdot n_i) \cdot \ln(N_d / n_i)]^{1/2}$$

15

$$+ (2kT/e) \cdot \ln(N_d / n_i)$$

(herein,  $V_{th}$ : threshold voltage,  $V_{fb}$ : flat band voltage,  $e$ : electron charge,  $n_i$ : intrinsic carrier density,  $C_{ox}$ : semiconductor device insulating film capacitance,  $N_d$ : activated dopant density,  $\epsilon_0$ : vacuum dielectric constant,  $\epsilon_{Si}$ : semiconductor dielectric constant,  $k$ : Boltzmann constant,  $T$ : absolute temperature), and obtains a dopant activation rate from the activated dopant density and an added dopant density.

13. The dose amount control program according to claim 11,

wherein the computing means obtains an activated dopant density by a

25 formula

$$V_{th} - V_{fb} = (e \cdot (N_d / n_i) \cdot n_i \cdot t_{Si}) / C_{ox} + (2kT / e) \cdot \ln(N_d / n_i)$$

(herein,  $V_{th}$ : threshold voltage,  $V_{fb}$ : flat band voltage,  $e$ : electron charge,  $n_i$ : intrinsic carrier density,  $t_{Si}$ : active layer thickness,  $C_{ox}$ : semiconductor device insulating film capacitance,  $N_d$ : activated dopant density,  $k$ : Boltzmann constant,  $T$ : absolute temperature), and obtains a dopant activation rate from the activated dopant density and an added dopant density.

14. A dose amount control program for a computer that controls

10 a dose amount in a semiconductor device, said computer comprising:

a computing means for computing a dopant activation rate from a threshold voltage and a flat band voltage of the semiconductor device;

15 a storage means for recording dopant activation rates that are obtained by the computing means with respect to a plurality of semiconductor devices with different production conditions;

a determining means for selecting a dopant activation rate of a predetermined semiconductor device from the storage means; and

a setting means for setting a dose amount, according to the dopant activation rate selected by the determining means.

20

15. The dose amount control program according to claim 14, wherein the computing means obtains an activated dopant density by a formula

$$V_{th} - V_{fb} = (e \cdot n_i / C_{ox}) (N_d / n_i) \cdot [(4\epsilon_0 \cdot \epsilon_{Si} \cdot kT) / (e^2 \cdot (N_d / n_i) \cdot n_i) \cdot \ln(N_d / n_i)]^{1/2}$$

25  $+ (2kT/e) \cdot \ln(N_d / n_i)$

(herein,  $V_{th}$ : threshold voltage,  $V_{fb}$ : flat band voltage,  $e$ : electron charge,  $n_i$ : intrinsic carrier density,  $C_{ox}$ : semiconductor device insulating film capacitance,  $N_d$ : activated dopant density,  $\epsilon_0$ : vacuum dielectric constant,  $\epsilon_{Si}$ : semiconductor dielectric constant,  $k$ : Boltzmann constant,  $T$ : absolute temperature), and obtains a dopant activation rate from the activated dopant density and an added dopant density.

16. The dose amount control program according to claim 14, wherein the computing means obtains an activated dopant density by a  
10 formula

$$V_{th} - V_{fb} = (e \cdot (N_d / n_i) \cdot n_i \cdot t_{Si}) / C_{ox} + (2kT / e) \cdot \ln(N_d / n_i)$$

(herein,  $V_{th}$ : threshold voltage,  $V_{fb}$ : flat band voltage,  $e$ : electron charge,  $n_i$ : intrinsic carrier density,  $t_{Si}$ : active layer thickness,  $C_{ox}$ : semiconductor device insulating film capacitance,  $N_d$ : activated dopant density,  $k$ : Boltzmann constant,  $T$ : absolute temperature), and obtains a dopant activation rate from the activated dopant density and an added dopant density.

17. A computer-readable recording medium that records a dose  
20 amount control program for a computer that controls a dose amount in a semiconductor device, said computer comprising:

a computing means for computing a dopant activation rate from a threshold voltage and a flat band voltage of the semiconductor device;  
a setting means for setting a predetermined dose amount according  
25 to the dopant activation rate obtained from the computing means; and

a means for outputting the dose amount that is set by the setting means.

18. The computer-readable recording medium according to  
5 claim 17 that records a dose amount control program, wherein the computing means obtains an activated dopant density from a formula  
$$V_{th} - V_{fb} = (e \cdot n_i / C_{ox}) (N_d / n_i) \cdot [(4\epsilon_0 \cdot \epsilon_{Si} \cdot kT) / (e^2 \cdot (N_d / n_i) \cdot n_i) \cdot \ln(N_d / n_i)]^{1/2} + (2kT/e) \cdot \ln(N_d / n_i)$$

(herein,  $V_{th}$ : threshold voltage,  $V_{fb}$ : flat band voltage,  $e$ : electron charge, 10  $n_i$ : intrinsic carrier density,  $C_{ox}$ : semiconductor device insulating film capacitance,  $N_d$ : activated dopant density,  $\epsilon_0$ : vacuum dielectric constant,  $\epsilon_{Si}$ : semiconductor dielectric constant,  $k$ : Boltzmann constant,  $T$ : absolute temperature), and obtains a dopant activation rate from the activated dopant density and an added dopant density.

15

19. The computer-readable recording medium according to  
claim 17 that records a dose amount control program, wherein the computing means obtains an activated dopant density from a formula  
$$V_{th} - V_{fb} = (e \cdot (N_d / n_i) \cdot n_i \cdot t_{Si}) / C_{ox} + (2kT / e) \cdot \ln(N_d / n_i)$$
  
20 (herein,  $V_{th}$ : threshold voltage,  $V_{fb}$ : flat band voltage,  $e$ : electron charge,  $n_i$ : intrinsic carrier density,  $t_{Si}$ : active layer thickness,  $C_{ox}$ : semiconductor device insulating film capacitance,  $N_d$ : activated dopant density,  $k$ : Boltzmann constant,  $T$ : absolute temperature), and obtains a dopant activation rate from the activated dopant density and an added dopant 25 density.

20. A computer-readable recording medium that records a dose amount control program for a computer that controls a dose amount in a semiconductor device, said computer comprising:

5 a computing means for computing a dopant activation rate from a threshold voltage and a flat band voltage of the semiconductor device;

a storage means for recording dopant activation rates that are obtained by the computing means with respect to a plurality of semiconductor devices with different production conditions;

10 a determining means for selecting a dopant activation rate of a predetermined semiconductor device from the storage means; and

a setting means for setting a dose amount according to the dopant activation rate selected by the determining means.

15 21. The computer-readable recording medium according to claim 20 that records a dose amount control program, wherein the computing means obtains an activated dopant density from a formula

$$V_{th} \cdot V_{fb} = (e \cdot n_i / C_{ox}) (N_d / n_i) \cdot [(4\epsilon_0 \cdot \epsilon_{Si} \cdot kT) / (e^2 \cdot (N_d / n_i) \cdot n_i) \cdot \ln(N_d / n_i)]^{1/2} + (2kT/e) \cdot \ln(N_d / n_i)$$

20 (herein,  $V_{th}$ : threshold voltage,  $V_{fb}$ : flat band voltage,  $e$ : electron charge,  $n_i$ : intrinsic carrier density,  $C_{ox}$ : semiconductor device insulating film capacitance,  $N_d$ : activated dopant density,  $\epsilon_0$ : vacuum dielectric constant,  $\epsilon_{Si}$ : semiconductor dielectric constant,  $k$ : Boltzmann constant,  $T$ : absolute temperature), and obtains a dopant activation rate from the activated 25 dopant density and an added dopant density.

22. The computer-readable recording medium according to claim 20 that records a dose amount control program, wherein the computing means obtains an activated dopant density from a formula

5 
$$V_{th} - V_{fb} = (e \cdot (N_d / n_i) \cdot n_i \cdot t_{Si}) / C_{ox} + (2kT / e) \cdot \ln(N_d / n_i)$$

(herein,  $V_{th}$ : threshold voltage,  $V_{fb}$ : flat band voltage,  $e$ : electron charge,  $n_i$ : intrinsic carrier density,  $t_{Si}$ : active layer thickness,  $C_{ox}$ : semiconductor device insulating film capacitance,  $N_d$ : activated dopant density,  $k$ : Boltzmann constant,  $T$ : absolute temperature), and obtains a dopant activation rate from the activated dopant density and an added dopant density.

23. A dose amount control device for a semiconductor device, comprising:

15 a means for inputting a threshold voltage and a flat band voltage of the semiconductor device, or a dopant density therein;

a computing means for computing a dopant activation rate from the threshold voltage and the flat band voltage;

20 a setting means for setting a predetermined dose amount according to the dopant activation rate obtained from the computing means; and

a means for outputting the dose amount that is set by the setting means.

24. The dose amount control device according to claim 23,

25 wherein the computing means obtains an activated dopant density from a

formula

$$V_{th} - V_{fb} = (e \cdot n_i / C_{ox}) (N_d / n_i) \cdot [(4\epsilon_0 \cdot \epsilon_{Si} \cdot kT) / (e^2 \cdot (N_d / n_i) \cdot n_i) \cdot \ln(N_d / n_i)]^{1/2} + (2kT/e) \cdot \ln(N_d / n_i)$$

(herein,  $V_{th}$ : threshold voltage,  $V_{fb}$ : flat band voltage,  $e$ : electron charge,

5  $n_i$ : intrinsic carrier density,  $C_{ox}$ : semiconductor device insulating film capacitance,  $N_d$ : activated dopant density,  $\epsilon_0$ : vacuum dielectric constant,  $\epsilon_{Si}$ : semiconductor dielectric constant,  $k$ : Boltzmann constant,  $T$ : absolute temperature), and obtains a dopant activation rate from the activated dopant density and an added dopant density.

10

25. The dose amount control device according to claim 23, wherein the computing means obtains an activated dopant density from a formula

$$V_{th} - V_{fb} = (e \cdot (N_d / n_i) \cdot n_i \cdot t_{Si}) / C_{ox} + (2kT / e) \cdot \ln(N_d / n_i)$$

15 (herein,  $V_{th}$ : threshold voltage,  $V_{fb}$ : flat band voltage,  $e$ : electron charge,  $n_i$ : intrinsic carrier density,  $t_{Si}$ : active layer thickness,  $C_{ox}$ : semiconductor device insulating film capacitance,  $N_d$ : activated dopant density,  $k$ : Boltzmann constant,  $T$ : absolute temperature), and obtains a dopant activation rate from the activated dopant density and an added dopant

20 density.

26. A dose amount control device for a semiconductor device, comprising:

25 a means for inputting production conditions of the semiconductor

device or design conditions of a device including the semiconductor device;

a computing means for computing a dopant activation rate from a threshold voltage and a flat band voltage of a semiconductor device to be measured;

5 a storage means for recording dopant activation rates that are obtained by the computing means with respect to a plurality of semiconductor devices with different production conditions;

a determining means for selecting a dopant activation rate of a predetermined semiconductor device from the storage means;

10 a setting means for setting a dose amount according to the dopant activation rate selected from the determining means; and

a means for outputting a dose amount that is set by the setting means.

27. The dose amount control device according to claim 26,  
15 wherein the computing means obtains an activated dopant density from a formula

$$V_{th} \cdot V_{fb} = (e \cdot n_i / C_{ox}) (N_d / n_i) \cdot [(4\epsilon_0 \cdot \epsilon_{Si} \cdot kT) / (e^2 \cdot (N_d / n_i) \cdot n_i) \cdot \ln(N_d / n_i)]^{1/2}$$

$$+ (2kT/e) \cdot \ln(N_d / n_i)$$

(herein,  $V_{th}$ : threshold voltage,  $V_{fb}$ : flat band voltage,  $e$ : electron charge, 20  $n_i$ : intrinsic carrier density,  $C_{ox}$ : semiconductor device insulating film capacitance,  $N_d$ : activated dopant density,  $\epsilon_0$ : vacuum dielectric constant,  $\epsilon_{Si}$ : semiconductor dielectric constant,  $k$ : Boltzmann constant,  $T$ : absolute temperature), and obtains a dopant activation rate from the activated dopant density and an added dopant density.

28. The dose amount control device according to claim 26, wherein the computing means obtains an activated dopant density from a formula

$$V_{th} - V_{fb} = (e \cdot (N_d / n_i) \cdot n_i \cdot t_{Si}) / C_{ox} + (2kT / e) \cdot \ln(N_d / n_i)$$

5 (herein,  $V_{th}$ : threshold voltage,  $V_{fb}$ : flat band voltage,  $e$ : electron charge,  $n_i$ : intrinsic carrier density,  $t_{Si}$ : active layer thickness,  $C_{ox}$ : semiconductor device insulating film capacitance,  $N_d$ : activated dopant density,  $k$ : Boltzmann constant,  $T$ : absolute temperature), and obtains a dopant activation rate from the activated dopant density and an added dopant 10 density.

29. An evaluation method of a semiconductor device comprising: measuring a drain current characteristics of a gate voltage of the semiconductor device;

15 obtaining an activated dopant density from the drain current characteristics of the gate voltage of the semiconductor device;

obtaining an added dopant density in the semiconductor device; and obtaining a dopant activation rate from the activated dopant density and the added dopant density.

20